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Abstract

Previous work has shown that semantic similarity results in a memory bias in which related words are more likely than unrelated words to be labeled as studied in recognition memory. I explored the relationship between semantic similarity memory bias and memory for unrelated words. I varied the strength of the related word memory bias by manipulating the proportion of related to unrelated words, and the type of related word used. I showed that as the bias for related words increases, the unrelated false alarm rate decreases. To further characterize the relationship between related and unrelated words, I examined how the related and unrelated words affect memory decisions when they are experienced separately at test. This manipulation diminished the related word memory bias, but the decrease in unrelated word false alarms remained. These findings suggest a compelling relationship between semantic similarity and unrelated items that warrants further investigation.

Characterizing the Relationship Between Related and Unrelated Items in
Recognition Memory

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B.A., Daemen College, 2011
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Thesis

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Experimental Psychology

Syracuse University

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Introduction

There has been considerable effort dedicated to understanding how semantic similarity alters responses in various memory paradigms (Thapar & Rouder, 2009; Dougal & Rotello, 2007; White et al., 2013; Cox, Kachergis & Shiffrin, 2013; Shiffrin, Huber, & Marinelli, 1995; Konkle, Brady, Alvarez, & Oliva, 2010). A common paradigm used to explore the role of semantics in memory is the Deese, Roediger, McDermott (DRM) paradigm, whereby participants study a list of similar words like knife, fork and plate, mixed with dissimilar words. Participants are then shown test words and asked to decide whether they think they have studied each word. There is robust evidence that are more likely to recognize both old and new related words compared to dissimilar words, reflected by higher hits (i.e. knife) and false alarms (i.e. spoon) for related words. This is indicative of a bias to believe the related words had been studied (Deese, 1959; Roediger & McDermott, 1995). It is clear that some aspect of the relatedness of the similar words leads to higher hit and false alarm rates for the related words. The present study seeks to better understand these effects in recognition memory by assessing the roles of memory and decision processes with related and unrelated words. For clarity, I will use the term “related” to refer to the categorized items, and “similarity” to refer to the distinguishing feature of the items.

While there have been many studies focusing on how similarity affects responses to related words (i.e. the bias previously mentioned), very little attention has been paid to understanding how related items in memory affect memorial

decisions for unrelated words. In the above example, there is robust evidence that a participant would false alarm to spoon. It is unclear whether or how this similarity bias affects the likelihood of false alarming to an unrelated word like “tree.” It is important to explore this relationship because the influence of similarity could stretch beyond the observed similarity bias in a way that provides insight into how exactly similarity is represented in memory. This study explicitly investigates the relationship between related items in memory and response to unrelated words. First I review literature on effects of similarity for related words, I then turn to possible memory effects for unrelated words.

Underwood (1965) proposed that false recognition for related words is initiated during encoding when participants, studying a word such as hot, might think of an associate like cold or warm. At test, if cold were presented as a lure, the participant might claim to recognize it because of the earlier implicit associative response. However, it is unclear whether participants are aware of these associations at study, or if there is an unattended implicit association being made through some associative network (Anderson & Bower, 1973; Collins & Loftus, 1975). For example, studying elephant, lion, buffalo, zebra and cheetah might result in strong African wildlife associative encoding and less encoding for specific features that are unique to any one animal.

Evidence from neuroimaging studies supports the theory that semantic associations are encoded when related words are studied. For example, Darsaud et al. (2011) found greater hippocampal activity at encoding for lists that were less likely to produce false recognition of related words than lists that were more likely

to produce related false recognition. Hippocampal activity is greater when participants remember the specific source of a tested word compared to when they only remember the word itself (Cansino, Maquest, Dolan & Rugg, 2002; Weis et al., 2004).

It could be that item-specific encoding is hindered when studying related words, which leads to encoding of indistinct information that is indicative of all the related words, resulting in greater susceptibility to related false alarms (Johnson, Raye, Mitchell & Ankudowich, 2012). Paz-Alonso and colleagues (2008) showed that, in healthy adults, hits and false alarms for related words were associated with similar activity levels in the left ventrolateral prefrontal cortex (VLPFC). When the related word “old” response bias is absent, so is the VLPFC activity, indicative of a link between the VLPFC and related item “old” response bias. Studies have also been conducted with repetitive transcranial magnetic stimulation (rTMS), a procedure designed to down modulate the area of the brain to which it is applied. When rTMS was administered to left anterior temporal cortex after studying a list containing some related words, the false alarms to related words were reduced with no reduction in correct recognition (Gallate, Chi, Ellwood & Snyder, 2009).

These results indicate that a specific region of the brain might be responsible for encoding indistinct, relational information and can only interfere with item specific encoding when active. There is greater activity in dorsolateral PFC (DLPFC) for relational encoding than for item encoding (Murray & Ranganath, 2007). There are also individual differences in susceptibility to related false alarms. For example, people who have reported that they recovered a childhood memory of sexual abuse

make more intrusions of related items during word list memory tests (Geraerts et al., 2009; Geraerts, 2012).

It is evident that similarity has a distinct affect on memory both behaviorally and neurophysiologically. Regardless of how exactly these associations are made; the strength of this effect is contingent on the number of related words presented at study (Hall & Kozloff, 1973; Hintzman, 1988; Shiffrin, Huber & Marinelli, 1995). For example, Hintzman (1988) presented study lists containing 0 to 5 related words and showed that false recognition for related words increased from 8% when no related words were studied to 35% when 5 related words were studied. Increasing the number of studied related words could be strengthening the memory for the common aspects of the words. Also, including unrelated items on a recognition test has been shown to increase the “old” bias for related words (Gunter, Ivanko & Bodner, 2005).

These results can be interpreted through Signal Detection Theory (SDT; Green & Swets, 1966), which provides a conventional framework to measure the accuracy and bias of recognition memory decisions. SDT assumes that memory strength varies along a single dimension for both studied and unstudied words (McNicol, 1972). Studied words generally have stronger memory strength on average than unstudied words, but there is considerable overlap of these two distributions. A criterion along the strength dimension determines the response on each trial; items with values above the criterion produce an old response and items below the criterion produce a new response (Figure 1A). The increase in hits and false alarms for related words can be explained in multiple ways within the signal

detection theory framework. The criterion could become more liberal, increasing the proportion of both distributions that elicits the old response (Figure 1B); this is indicative of a decision to require less memory strength for related items to elicit an old response. Alternatively, both distributions could shift to the right (Figure 1C), which is indicative of stronger overall memory for the words. This would reflect the fact that related words feel more familiar. Therefore, similarity may lower the amount of evidence needed to claim a related word has been studied (criterion shift). Conversely, similarity may make related words feel more familiar, by increasing the amount of memory strength for these words (distribution shift). Or, there might some combination of increased familiarity and more liberal criterion.

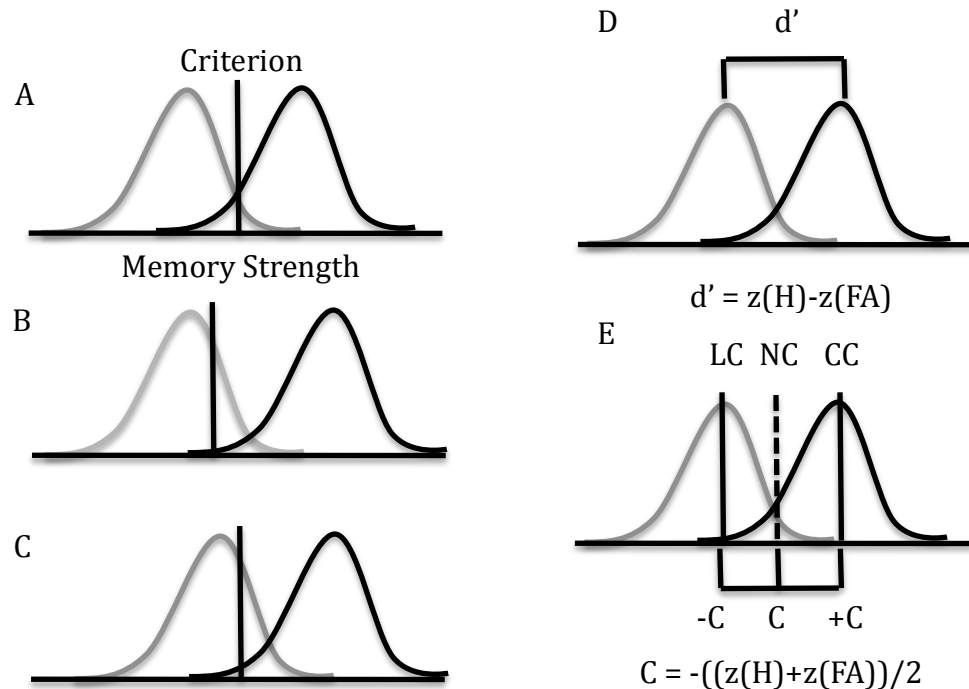


Figure 1. Representation of semantic similarity by signal detection theory. A) Representation of signal detection theory. B) Criterion shift. C) Distribution memory strength shift. Foil distribution in grey, target distribution in black. D) Representation of the d' SDT parameter. E) Representation of the C SDT parameter. LC: liberal criterion, NC: neutral criterion, CC: conservative criterion.

Miller and Wolford (1999) argued that a liberal criterion shift is responsible for the high hit and false alarm rate of related words. They claimed that subjects develop meta-knowledge about the theme of a studied list, and can use compliance with this theme as evidence that the word was studied. Further, they implicate a faulty decision process for the liberal criterion shift; inferring that participants consciously decide to use an erroneous decision process by strategically guessing that related words are old. They therefore consider this to be a bias to call related words old and not a fundamental aspect of human memory.

The present study sought to contrast these mechanisms by focusing on the effects of similarity and study/test list composition on response rates for related and unrelated items. The focus on both related and unrelated items puts stronger constraints on the potential mechanisms involved in this phenomenon. Miller and Wolford (1999) support this argument by showing that a change in the SDT bias parameter (criterion) can explain the different response rate for related items. A flaw in Miller and Wolford's interpretation of the SDT bias parameter was highlighted by both Wixted and Stretch (2000) and Wickens and Hirshman (2000); a change in response bias for a set of words can be explained by both a shift in criteria or a shift in the underlying distributions. Gallo, Roediger and McDermott (2001) informed participants about this memory effect before or after studying a list of words comprised of related and unrelated words. A decrease in related word false alarms was only observed when participants were warned before they studied the list of words. There was no change in related word false alarms if participants were warned in between study and test. Gallo, Roediger and McDermott (2001)

interpret these results as evidence that, while participants can change their study habits to account for relatedness, they do not alter their decision process. Therefore, if a criterion shift implies conscious control of the decision making process, then relatedness affects something other than criterion placement. Thus, related items in memory lend to bias to respond old either through a weaker criterion or stronger memory strength for the related items.

Considerably less attention has been paid to understanding how similar items in memory affect memorial decisions for unrelated words. However, there has been some exploration into this topic. For example, Dennis and Chapman (2001) manipulated the number of related words that were presented at study and then tested participants on studied related, unstudied related, and unstudied unrelated words. They showed that as the number of related words at study increased, the number of unrelated word false alarms decrease. They named this phenomenon the Inverse List Length Effect, claiming that it is the total number of related words that are responsible for the changing unrelated word false alarm response rate. This supports the idea that relatedness affects memory in a way that stretches beyond memory for the related items. However, Dennis and Chapman did not have participants study unrelated words, and therefore could not observe unrelated word hit rates. They mixed or blocked multiple categories of related words at study, which complicates the relationship between relatedness and unrelated words in memory because they could be observing an effect that is unique to their multiple category design. Further, they implicate total number of related words as the culprit responsible for this phenomenon but, due to their omission of unrelated words at

study could not test whether related word proportion to unrelated words play a role in unrelated word response rate.

The Roediger & McDermott (1995) article first characterized the response bias for similar words. Since then, the DRM paradigm has been studied extensively and in fact, this article has been cited almost 3000 times since its publication. In spite of the extensive work in this field, unrelated word response rates have mostly been used as a reference point to compare to related word response rates to identify the existence and strength of the response bias in various manipulations of the DRM paradigm. Further, the standard methods for the DRM paradigm is to have participants study only related words, and are tested on studied and unstudied related words and unrelated unstudied words. This methodology is useful for inducing an “old” response bias for related words, but is not informative when attempting to observe the relationship between response rates for related and unrelated words.

It is important to understand this relationship for a few reasons. First, if unrelated word response rates are simply used as a reference point to observe related word “old” response bias, then a decrease in “old” responses for unrelated words will be perceived as a strong “old” response bias for related words, which will confound the interpretation of this bias. Second, and more importantly, understanding the relationship between response rates for related and unrelated words may inform on the specific processes that result in an “old” response bias for related words. As previously mentioned, Gunter, Ivanko & Bodner (2005) showed that including unrelated words on the recognition test increases the “old” bias for

related words compared to purely related test lists. They claim that the inclusion of unrelated test items encourages responding based on gist, or general information relevant to the related words as a whole, and not based on item specific information. While this interpretation is entirely reasonable, it is possible that there is a more complex relationship between memory for related and unrelated words when they are studied and tested simultaneously. If this is considered in terms of signal detection theory, it stands to reason that these words would be subject to the same decision criterion. Exploring this relationship could inform in a more general sense as to the appropriate framework in which to discuss the related word “old” bias phenomenon. In this regard, discovering a relationship between response rates for related and unrelated lends credence to the signal detection framework in the sense that it assumes both types of words are subject to the same decision making criterion.

In order to test the relationship between response rates for related and unrelated words in recognition memory, I wanted to induce different levels of similarity bias to see if this variation affects memory for unrelated words. I also attempted to determine whether similarity influences familiarity (memory), criterion placement (decision process), or both. In order to do this, I replicated the design of White et al. (2013). Briefly, participants were asked to study a list of words containing a high or low proportion of either negatively emotional words or animal names mixed with unrelated words. White et al. found that a high proportion of related words induced higher hit and false alarm rate than low proportion, and negative emotional words induced higher hit and false alarm rate than animal

names. However, White et al. did not investigate the unrelated word response rate between these conditions. That being said, the published figure in the White et al (2013) article does appear to show a trend indicative of less unrelated word false alarms when the related word hits and false alarms were higher. Therefore, I predict that as bias for the related words increase, the response rate for the unrelated words will decrease. In other words, as bias to recognize related words increased, bias to recognize unrelated words decreased.

Experiment 1

The goal of the first experiment was to replicate the experimental design of White et al. (2013) in order to test how related words, which elicit an old bias for those words at test, affect responding for the unrelated words which are being studied alongside the related words. To do this, I manipulated the study and test lists to induce different levels of similarity bias. I did this by having two different types of related words, negative emotional or animal and by changing the proportion of these words compared to the unrelated words. This resulted in a total of four experimental conditions, a low and high proportion of either negatively emotional words or animal words. I hypothesized that, as shown in White et al (2013) (figure 2), the high proportion of related words would elicit a higher percent of old responding for those words, and the negatively emotional words would elicit a higher bias to respond “old” compared to the animal words. Further, in line with the findings of Dennis and Chapman (2001), I hypothesized that in conditions with

higher related old responding; there would be a decrease in the unrelated word old responding.

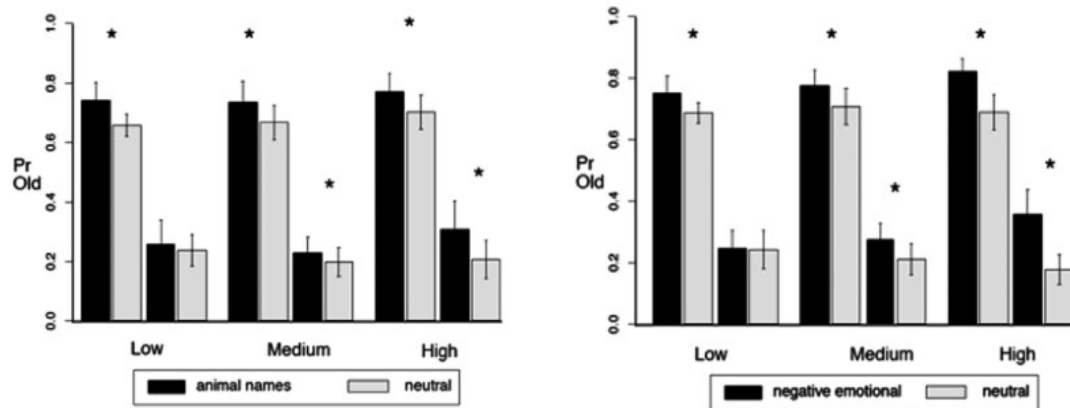


Figure 2. White et al (2013). Hit and false alarm rates averaged across participants. Dark bars represent related words (emotional or animal names) and light bars represent unrelated words. Error bars represent 95% confidence intervals.

Methods

Participants

Syracuse University undergraduate students participated in the experiment for course credit. The experiment includes 4 conditions the negative high proportion condition, negative low proportion, animal high proportion and animal low proportion which included 32, 31, 34 and 36 participants respectively for a total of 133 participants. All participants consented to this IRB approved experiment.

Materials

The stimuli were the same as in White et al., 2013 and consisted of a set of matched negative emotional and neutral words and a separate set containing matched animal names and neutral words. The negatively emotional-neutral word pools were sampled from the ANEW pool of words (Bradley & Lang, 1999). The animal name-dissimilar word pools were taken from the Van Overschelde, Rawson, and Dunlosky (2004) database. The word pools were matched on word frequency (Francis & Kucera, 1982).

Procedure

Participants were asked to study a single list of words, and then asked to complete distractor math problems before being asked to discriminate between old and new words at test. The study list consisted of 24 words, the test list of 48 (half studied). The proportion and type of related words varied across participants in a 2 X 2 design. Each participant received either the animal or negative words at a low or high proportion. The low proportion of related words consisted of 25% related words; the high proportion consisted of 50% related words. If a participant studied 12 related and 12 unrelated words, they were tested on all those words, plus 12 unstudied related and 12 unstudied unrelated words (Figure 3). Each studied word was presented for 2500 ms with 500 ms of black screen in between stimuli. Participants are asked to study each word for a later, unspecified memory test. After all study words were presented, participants were asked to respond to 15 math problems deciding if the solutions are accurate or not as a distractor before the test section of the experiment. At test, participants are prompted to respond by pressing either the “z” or “/” keys. Button order was counter balanced in order to rule out the

affects of handedness. I monitored the response time and accuracy of the participants.

Results

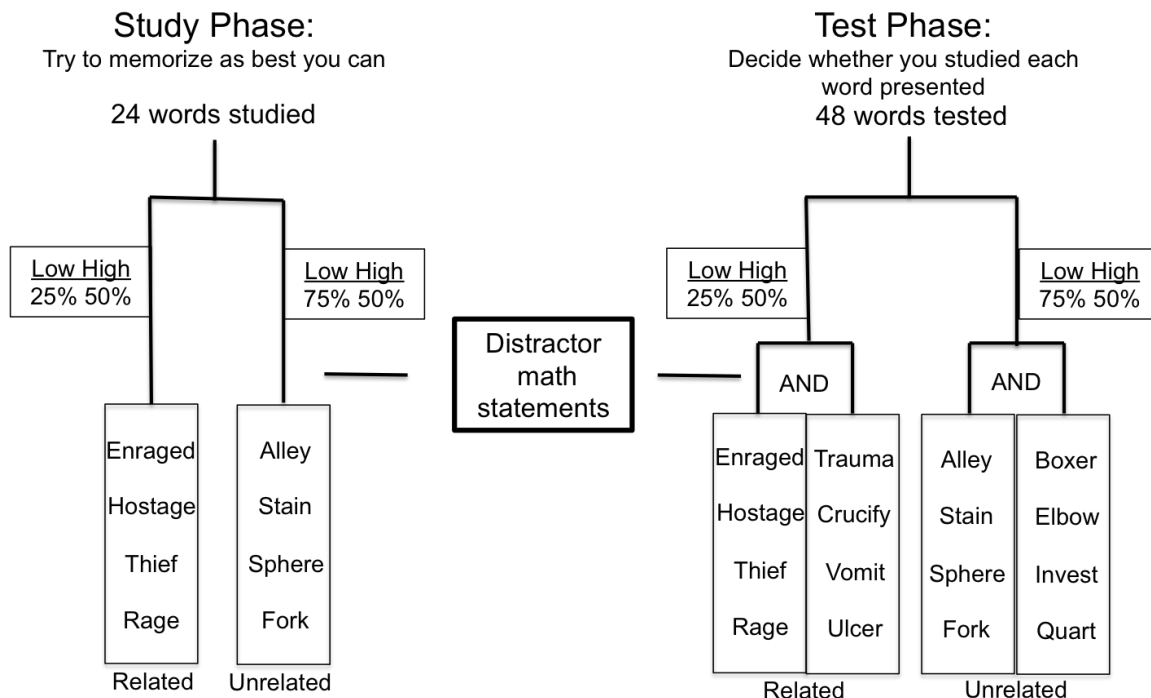


Figure 3. Representation of experimental paradigm. The Low/High distinction refers to the proportion of categorized words in the list, and was manipulated between subjects.

In order to observe the relationship between related and unrelated words in each condition, the data was analyzed based on the response rates for related and unrelated words in each condition separately. This data are analyzed in terms of the signal detection theory parameters d' and C (figure 1 D and E, respectively). d' is used as a standard parameter to quantify accuracy and C is used to quantify

criterion placement. As previously discussed, this work is motivated by the relationship between response rates for related and unrelated words in conditions when varying degrees of a related word “old” bias is present. Therefore, I am primarily concerned with the relationship between the C parameter for related and unrelated words in these various conditions. This is because the C parameter is a quantification that can be used to identify a bias to consider certain words “old” or “new.” A positive C is indicative of a conservative criterion, and is a result of there being fewer hits and false alarms for the relevant set of words. Alternatively, a negative C is indicative of a liberal criterion and is a result of there being many hits and false alarms for the relevant set of words. Considering the implication of the positive and negative C, it is important to not only compare C between groups, but also compare with 0. I used the calculation of Bayes factors to find evidence for or against the null hypothesis (C different than 0) using the Jeffery-Zellner-Siow prior with an assumed effect size scaling of $r = 1$, as recommended by Rouder et al. (2009, <http://pcl.missouri.edu/bf-one-sample>). The Bayes factor BF_{01} may be interpreted as the ratio of evidence for the null hypothesis H_0 to the evidence for its alternate H_1 . For example, a Bayes Factor of $BF_{01} = 10$ may be thought of as stating that it is 10 times more likely that this data came from a distribution centered around H_0 than H_1 . We map Bayes factors to a verbal account for or against H_0 using the modified classification scheme of Jeffreys (1961) as described by Wetzels, et al. (2011). While memory discriminability is not the primary interest of the present work, I analyzed d' in order to interpret performance in each condition. This is because the relationship between d' and C is complex, and changes in one can often be masked,

or falsely identified due to changes in the other (Pastore et al., 2003). In depth analysis of this relationship is beyond the scope of this work, but I analyzed d' in order to test for any possible confounds in accuracy that could affect how I interpret the C parameter. Hits and false alarm rates of 1 and 0 lead to an issue calculating C and d' because the corresponding z score is positive or negative infinity, respectively. To correct for this, rates of 0 are replaced with $.5/n$, and rates of 1 are replaced with $(n - 0.5)/n$, where n is the number of trials (Macmillan & Kaplan, 1985). Finally, I also displayed hit and false alarm rates in order to be transparent in regards to the underlying factors that contribute to changes in C and d' (Table 1).

Multiple two-way between conditions ANOVAs were conducted that test the effect of proportion and type of related word on the hit rate, false alarm rate, C and d' for related and unrelated words. The main effect of proportion of related word on related word C was significantly different between conditions [$F(1, 129) = 4.359, p = .039$]. The main effect of type of related word on related word C was not significantly different between conditions [$F(1, 129) = 3.513, p = .063$]. The proportion and type interaction was not significant for related word C [$F(1, 129) = .190, p = .663$]. This means that the related word C changes significantly as proportion of related word increases, and while type of related word was not significant, there is clearly a trend for a decrease in related word C if the related word is negative emotional as opposed to animal words. These results show that the experimental manipulations successfully induced different levels of similarity bias.

The 2-way between conditions ANOVA to test whether the C for unrelated words is significantly different between conditions. The main effect of proportion of

related word on unrelated word C was not significantly different between conditions [$F(1, 129) = 1.131, p = .290$]. The main effect of type of related word on unrelated word C was significantly different between conditions [$F(1, 129) = 5.050, p = .026$]. The proportion and type interaction was not significant for unrelated word C [$F(1, 129) = .801, p = .373$]. This means that the unrelated word C changes significantly as the type of related word changes from negative emotion to animal. This change is indicative of the more conservative criterion for unrelated words if the type of related word is negative emotional.

In order to test whether the C for each type of word and in each group is significantly different from 0, Bayes factors were calculated. The negative high proportion C $BF_{01} = 7.02$ and 141 for related and unrelated words respectively. This is evidence that both Cs in the negative high proportion group are significantly different from 0, indicating a liberal criterion used for the related words, and a conservative criterion used for the unrelated words. The negative low proportion C $BF_{01} = 6.29$ and 24.2 for related and unrelated words respectively. This is evidence that both Cs in the negative low proportion group are significantly different from 0, indicating a liberal criterion used for the related words, and a conservative criterion used for the unrelated words, although to a lesser degree compared to the negative high proportion. The animal high proportion C $BF_{01} = 3.98$ and 19.32 for related and unrelated words respectively. This is weak evidence that the related word C is significantly different from 0, and strong evidence that the unrelated word C is significantly different from 0. Importantly, the evidence that both Cs are different than 0 in the animal high proportion group is weaker than both the negative high

proportion and the negative low proportion groups. The animal low proportion C $BF_{01} = 5.65$ and 4.38 for related and unrelated words respectively. It is important to note that the mean for the related word C is positive, so while there is fair evidence that it is different than 0, it is not indicative of the liberal C seen in the other groups and primarily the negative high proportion group. Also, the animal low proportion group has the weakest evidence that the unrelated word C is significantly different than 0. These results suggest that in conditions where a related word “old” bias is present, a unrelated “new” bias is also present and to a similar degree. According to the results of the 2 way between conditions ANOVA testing the effect of proportion of related word and type of related word on d' shows that there is no significant difference in d' between conditions. The related word d' was nonsignificant for proportion, type, and the interaction; $[F(1, 129) = .180, p = .672]$, $[F(1, 129) = .266, p = .607]$, and $[F(1, 129) = 1.652, p = .201]$ respectively. Similarly, there is no significant difference in d' for the unrelated word between groups regardless of proportion, type and the interaction; $[F(1, 129) = 2.148, p = .145]$, $[F(1, 129) = .479, p = .490]$, and $[F(1, 129) = 1.282, p = .260]$ respectively. These results indicate no difference in accuracy for either related or unrelated words between any groups. This is a somewhat surprising finding, and highlights the importance of also observing the raw hit and false alarm rates. The results of the 2-way ANOVA designed to analyze the effect of proportion and type of related word on related and unrelated word hit and false alarms rates depicted only one significant finding; the effect of proportion on unrelated word false alarms $[F(1, 129) = 4.247, p = .041]$, all other findings were not significant. The main effect of type of related word on

unrelated false alarms and the interaction are $[F(1, 129) = 2.719, p = .102]$ and $[F(1, 129) = 1.369, p = .244]$ respectively. The results for the main effect of proportion, type of related word and the interaction on related word false alarms are $[F(1, 129) = 2.172, p = .143]$, $[F(1, 129) = 2.061, p = .154]$ and $[F(1, 129) = 1.671, p = .198]$, respectively. The results for the main effect of proportion, type of related word and the interaction on related word hit rate are $[F(1, 129) = 3.290, p = .072]$, $[F(1, 129) = 1.367, p = .244]$ and $[F(1, 129) = .964, p = .328]$, respectively. The results for the main effect of proportion, type of related word and the interaction on the unrelated word hit rate are $[F(1, 129) = .335, p = .564]$, $[F(1, 129) = .969, p = .327]$ and $[F(1, 129) = .149, p = .700]$, respectively.

The bias observed through the C parameter is clearly represented in both hits and false alarms for related words (Table 1 and Figure 5 A). This change in bias can be seen as change in the data points on the diagonal from the bottom left of the figure to the top right. Change in this direction is indicative of changes in both hits and false alarms. Changes in the opposite diagonal (from top left to bottom right or vice versa) are indicative of changes in accuracy, where hits and false alarms now change in an indirect relationship. However, observation of the hits and false alarms for unrelated words seems to show that the changes in C between conditions is primarily carried by the false alarm rate (Table 1 and Figure 5B). This is an interesting result that may be indicative of the shape of the underlying memory distributions for studied and unstudied words. More specifically, the distribution of memory strength for studied words is considered to be unequal in comparison to the memory distribution for unstudied words (Egan, 1958). Considering this, it is

possible that a shift in criterion (C) could result primarily in a change in the false alarm rate depending on where this shift takes place in the memory strength continuum (Pastore et al., 2003). This subject is discussed in greater detail in the discussion section.

Group	Related Hit Rate		Unrelated Hit Rate		Related False Alarm Rate		Unrelated False Alarm Rate		Related C		Unrelated C		Related d'		Unrelated d'	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EXP 1																
Negative High Proportion	0.786	0.096	0.685	0.12	0.328	0.145	0.17	0.124	-0.178	0.058	0.28	0.066	1.328	0.457	1.592	0.57
Animal High Proportion	0.782	0.088	0.72	0.133	0.26	0.133	0.18	0.125	-0.046	0.04	0.192	0.055	1.531	0.653	1.646	0.63
Negative Low Proportion	0.769	0.143	0.68	0.166	0.259	0.134	0.191	0.165	-0.034	0.065	0.269	0.075	1.521	0.638	1.551	0.80
Animal Low Proportion	0.726	0.133	0.696	0.156	0.253	0.165	0.26	0.144	0.048	0.062	0.066	0.062	1.434	0.783	1.328	0.74
EXP 2																
Test Separation	0.735	0.1	0.684	0.168	0.261	0.133	0.18	0.105	0.017	0.295	0.259	0.343	1.347	0.475	1.536	0.64

Table 1 Experiment 1 and 2 Results. Mean and standard deviation of response rates, C and d' by condition and type of word (related or unrelated).

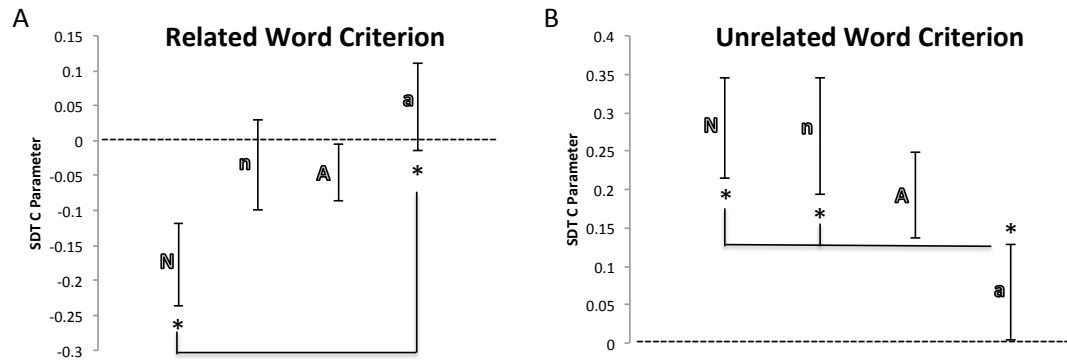


Figure 4. Signal Detection Theory C parameter by condition A) Related word C B) Unrelated word C. N: Negative high proportion, n: negative low proportion, A: Animal high proportion, a: Animal low proportion. * indicates significant difference, error bars represent standard error of the mean.

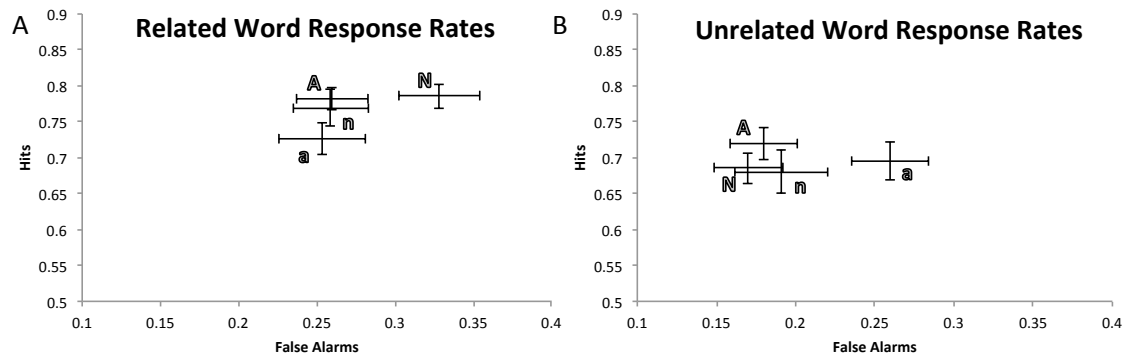


Figure 5. Response rates plotted by condition for A) Related and B) Unrelated words. . N: Negative high proportion, n: negative low proportion, A: Animal high proportion, a: Animal low proportion. Error bars represent standard error of the mean.

Conclusion

These experiments reflect the standard DRM paradigm finding, that “old” response bias for related words can be increased if the proportion of related words is increased, and if the type of word is emotional compared to animal. Importantly, bias rate for unrelated words seems to mirror that of related words. This relationship, between related “old” response bias and unrelated response rates,

suggests that there could be an interaction between memory strength for each type of word, which produces a complex interaction with decision criterion. More specifically, the memory strength for the related words could be increased compared to the memory strength for the unrelated words. This is because much of what is encoded is relevant for all related words. Due to the fact that these words are studied and tested together, they are subject to the same decision criterion (Brown & Steyvers, 2005). This may lead participants to adapt a decision criterion that is too liberal for the related words, and too conservative for the unrelated words, but is optimal considering all words being tested. In the next experiment I test this theory further by manipulating the test list composition in order to further probe the relationship between memory strength and decision criterion.

Experiment 2

The results of Experiment 1 showed an inverse relationship between related and unrelated word response rate. As the bias to label related words “old” increased, the propensity to label unrelated words “old” decreased. It remains unclear whether this relationship reflects properties of the memory trace for the items, influences on decision criteria, or both. More specifically, I do not know whether the same criterion is being used across the different conditions, or if

participants are able to adopt a varying criterion in response to the perceived similarity of some of the words and the contrast between these words and the unrelated words. There is a complex body of literature on the topic of criteria placement in recognition memory. Starns et al. (2010) showed that if different words are studied together but tested separately, a different criterion could be adopted for each set of tested words. Within the same test list, criterion is thought to be positioned based on a small sample of test items and the subjects' preconceived notion about the test distribution (Singer & Wixted, 2006). However, it has been theorized that criterion can be updated based on a few consecutive distractor test items (Gillund & Shiffrin 1984), or just a single preceding distractor test item (McNamara & Diwadkar, 1996). While there is a significant body of evidence for within list criterion shifts (Niewiadomski & Hockley, 2001; Reder, 1987), this theory is faced with some skepticism because of the momentous cognitive demand that would be necessary for continual criterion adjustment (Niewiadomski & Hockley, 2001). Thus, it is unlikely that criteria changes during a test list without explicit information that would warrant this change.

In Experiment 2 I explored how the related and unrelated words affect memory decisions when they are experienced separately at test. This allowed us to assess the impact of decision criteria when participants are given the opportunity to adjust between the related and unrelated words. As shown in experiment 1, the negative high proportion condition showed the largest effect of related words. Because I am interested in further characterizing the relationship between related and unrelated bias rate, I focused on the negative high proportion condition in

experiment 2. The adapted negative high proportion condition used in experiment 2 will be referred to as the negative high proportion test separation condition from here on. I predict that allowing for the use of separate criteria at test will reduce the difference in response bias between the related and unrelated words.

Methods

The methods are the same as discussed in experiment 1 except for the test portion of the experiment. At test, participants were still tested on all studied and an equal number of related and unrelated unstudied words. However, participants were tested on all related words first (studied and unstudied), and then all unrelated words next or vice versa. The order of the type of tested word was randomly assigned to each participant. 26 participants were included in this experiment.

Results

The test separation condition data are compared to the negative high proportion condition from Experiment 1. This was done to observe the changes in response rates for related and unrelated words in terms of C when the words are tested simultaneously or separately. Interestingly, it is clear that testing the related and unrelated words separately diminished the related word “old” bias, but did not alter the unrelated word “new” bias. This is clearly a result of changes, or lack of

changes in both hits and false alarms (Figure 6). This result can be quantified in terms of C . I conducted independent t -tests to analyze the difference in C for related and unrelated words between the negative high proportion and the test separation group. The C for related words is significant $t(56) = -2.352$, $p = .022$, but not significant for unrelated words $t(56) = .233$, $p = .817$ (figure 7). This indicates the diminished “old” bias for related words and maintained “new” bias for unrelated words. As previously reported, the negative high proportion C $BF_{01} = 7.02$ and 141 for related and unrelated words respectively. The test separation C $BF_{01} = 4.6$ and 116 for related and unrelated words respectively. Note that the weak evidence of related word C being different than 0 is evidence that it is more positive than 0, not more negative like the negative high proportion group. This result is consistent with the diminished “old” bias for related words but maintained “new” bias for unrelated words in the test separation condition. This finding is also supported by the analysis of hit and false alarm rates with a significantly higher related word hit, $t(56) = 2.01$, $p = .024$ and false alarm rate, $t(56) = 1.88$, $p = .032$ and no significant differences in unrelated word hits $t(56) = 0.036$, $p = .486$, or false alarms $t(56) = .326$, $p = .373$. There were no significant differences in d' between conditions for related or unrelated words $t(56) = -.161$, $p = .716$, $t(56) = .366$, $p = .716$, respectively.

Conclusion

These results indicate that, interestingly, when the related words were tested separately from the unrelated words, the bias to call the related words old is

diminished. However, the unrelated word old responses did not significantly change when the words were tested together or separately. This could indicate that the influence of studying the related and unrelated words together and testing them together affects the related words differently than the unrelated words. It is possible that changes in criteria placement could produce these results. If the memory strength for the related words were stronger than for the unrelated words, the ideal criterion for the related words would be more conservative compared to the unrelated words. When the words are tested together, it stands to reason that, because only one criterion can be adopted, it would be somewhere in between the two ideal locations. The criterion for the related words, when tested separately, could be shifting more conservatively compared to the shared criterion when the related and unrelated words are tested together. However, if this were the case, a fair assumption would be that the criterion for the unrelated words should shift more liberally, eliminating the “new” response bias when the words are tested separately. Our data maintain the unrelated word response bias even when these words are tested separately. Regardless of the continued presence of the unrelated word “new” bias, it is possible that being tested on the related words separately results in a situation where the memory strength for these words is still strong, but the criterion, which is no longer under the influence of the memory strength for unrelated words, can become relatively more conservative to account for this stronger memory. The next experiment is designed to test this hypothesis by utilizing an initially pure related word test list that progress into a mixed list.

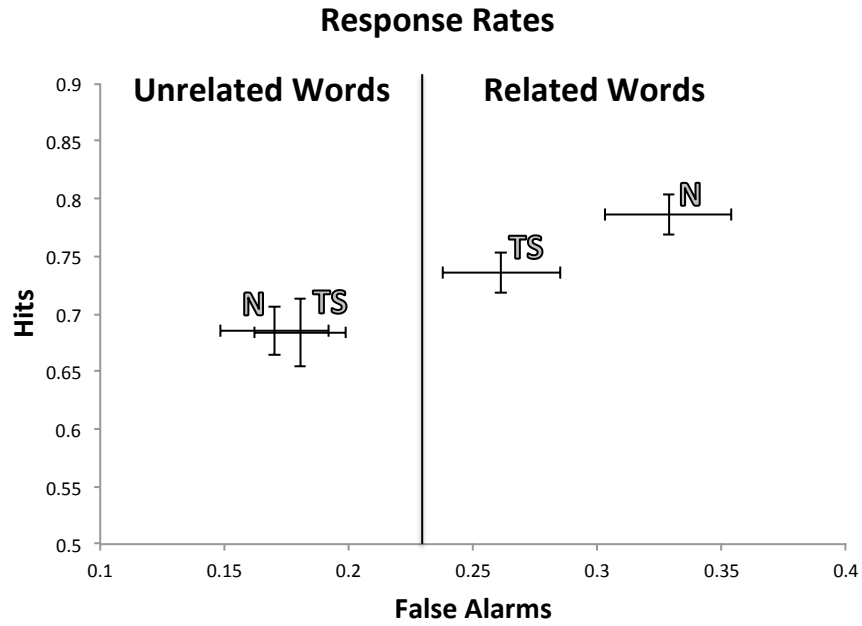


Figure 6. Response rates plotted by condition for related and unrelated words. . N: Negative high proportion, TS: Test Separation. Error bars represent standard error of the mean.

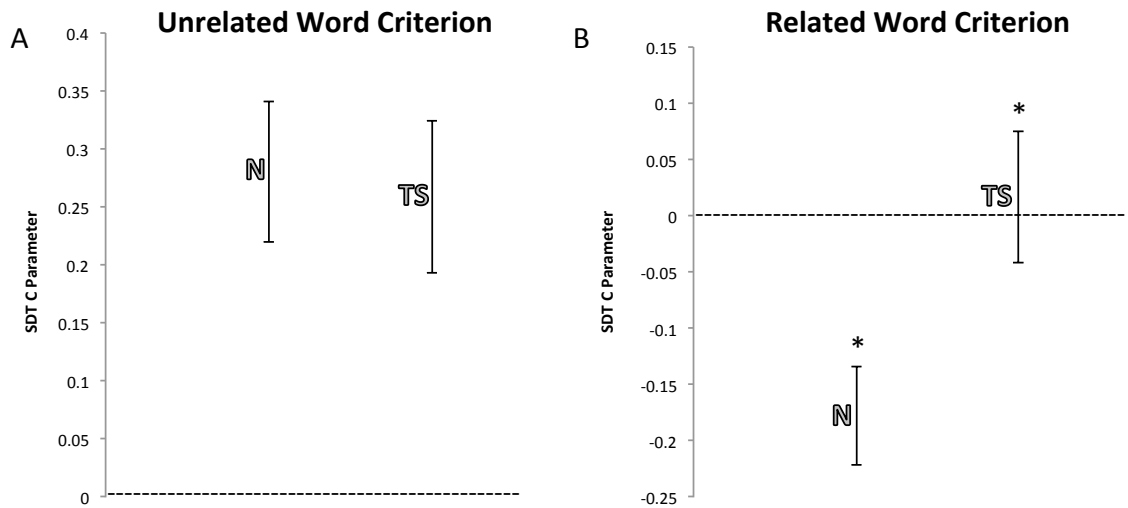


Figure 7. Signal Detection Theory C parameter by condition A) Related word C B) Unrelated word C. N: Negative high proportion, TS: Test Separation. * indicates significant difference, error bars represent standard error of the mean.

Experiment 3

The results of the second experiment showed that when related and unrelated words are studied together and tested separately, the “old” bias for related words is diminished compared to experiment one, when they are studied and tested together. It is possible that this is because, when tested separately, participants can adopt a criterion that is more appropriate for these words considering their stronger memory. Alternatively, the perceived increase in memory strength for these words is caused by the distinction between the related and unrelated words at test. Therefore, when the related words are tested separately, the memory strength for these words is not increased, and the criterion does not need to relocate for the bias to be diminished. For the third experiment, I decided to test this by subjecting participants to the same mixed study list used in experiment one and two. Participants were grouped into one of two conditions that would differ based on the composition of the test list they received. Participants wither had a pure related or unrelated test list, which halfway through the test list, would then begin to include the relevant missing type of words. The motivation behind this experimental design is that if the pure related words still produce increased memory strength, but the criterion becomes more conservative to adjust for this, then once the unrelated words are introduced, they should be subject to this more conservative criterion. This can be compared to the condition where participants are first tested on a pure unrelated list, which should induce a more liberal criterion

due to the relatively weaker memory for these words, and the unrelated words at the second half of the test list will be subject to a relatively more liberal criterion.

Methods

The methods are similar to that of experiment one and two. Except in this experiment, participants are only given one longer study/test list consisting of 64 studied words and 128 tested words. The first 64 tested words are either purely related (related precedent) or unrelated words (unrelated precedent) depending on the condition; with an equal number studied and unstudied. The second 64 tested words are a mix of related and unrelated words, equal number studied and unstudied. The order of the type of tested word was randomly assigned to each participant. A total of 83 participants were included in the experiment, 39 in the related precedent condition and 44 in the unrelated precedent condition.

Results

The goal of the third experiment is to test whether being subjected to a pure related test list induces a conservative criterion compared to an unrelated test list. Therefore, only the second half of the test list was analyzed here in order to compare differences in criterion between the pure related and unrelated precedents. I observed hit rates, false alarm rates and analyzed C and d' (Table 2). As predicted, there appears to be a change in both hits and false alarms for

unrelated words with the increase in “old” responding for unrelated words in the unrelated precedent condition compared to the related precedent condition. It stands to reason that this same relationship would be apparent in the related words as well. However, the change in related word response rates between conditions seems to be particularly in the hit rate, with the unrelated precedent leading to a higher hit rate for related words. To analyze this relationship, C parameters were compared between precedents for each word type using t-tests. The C for unrelated words is significantly different $t(81) = 1.863, p = .033$. As predicted, this indicates that the unrelated words were subjected to a more conservative criterion in the related precedent condition. The C for related words, while the trend is as predicted, is not significant $t(81) = .382, p = .352$. There are no significant differences in hit or false alarm rates between groups for either type of words: Related word hit rate $t(81) = -1.42, p = .08$, related word false alarm rate $t(81) = 0.076, p = .467$, unrelated word hit rate $t(81) = -1.42, p = .08$, unrelated word false alarm rate $t(81) = -1.31, p = .097$. The d' was not significantly different for related or unrelated words $t(81) = -1.44, p = .077, t(81) = -0.099, p = .461$, respectively.

Conclusion

The result from the third experiment is partially in line with our predictions. The related precedent clearly subjected the unrelated words to a more conservative criterion compared to the unrelated precedent. However, if the related precedent truly induced a more conservative criterion, it stands to reason that this would have

affected the related words in the same way. The related precedent seemed to decrease the hit rate of the related words. This could be indicative of a criterion shift that doesn't alter hits and false alarms equally, possibly due to an unequal variance between these distributions. Alternatively, the related precedent could cloud memory for related words, leading to decrease performance specifically for the related words on the second half of the test list. While this should be represented in changes in d' , there was no significant difference in d' for related words between conditions, but there was certainly a trend ($t = -1.44$, $p = .077$). Overall, there is fair evidence here for the induction of a more conservative criterion caused by the pure related test list but future research will be necessary to elucidate the complex relationship between accuracy and criterion that could be confounding the results of the present research.

Group	Related Hit Rate		Unrelated Hit Rate		Related False Alarm Rate		Unrelated False Alarm Rate		Related C		Unrelated C		Related d'		Unrelated d'	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Related Precedent	0.678	0.184	0.545	0.177	0.274	0.166	0.114	0.089	0.083	0.504	0.619	0.352	1.233	0.649	1.481	0.722
Unrelated Precedent	0.729	0.149	0.598	0.163	0.272	0.186	0.143	0.107	0.041	0.534	0.474	0.338	1.440	0.718	1.497	0.741

Table 2. Mean and standard deviation of response rates, C and d' by condition and type of word (related or unrelated) for experiment 3.

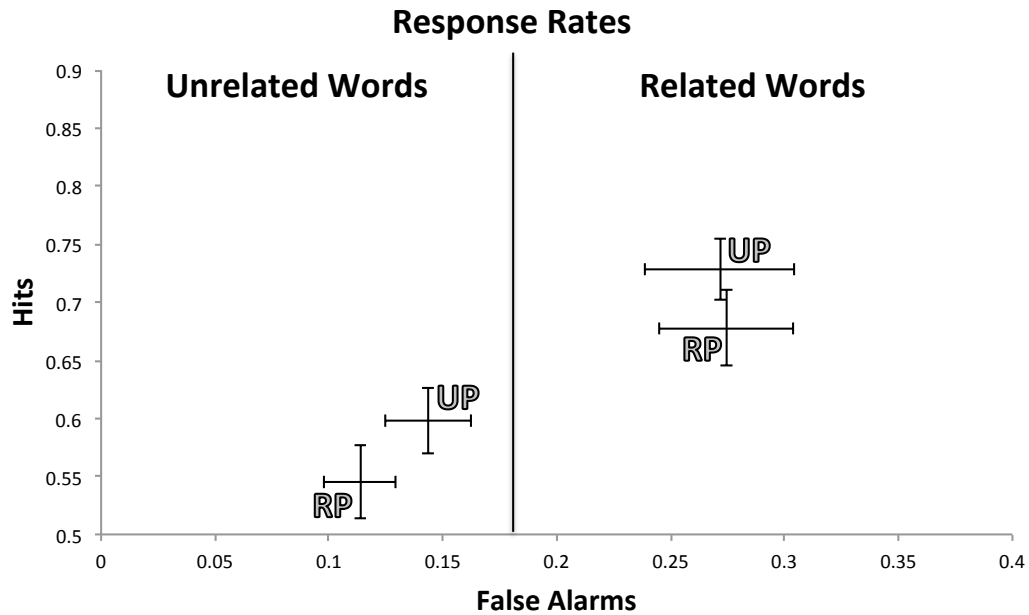


Figure 8. Response rates plotted by condition for related and unrelated words. . RP: Related Precedent, UP: Unrelated Precedent. Error bars represent standard error of the mean.

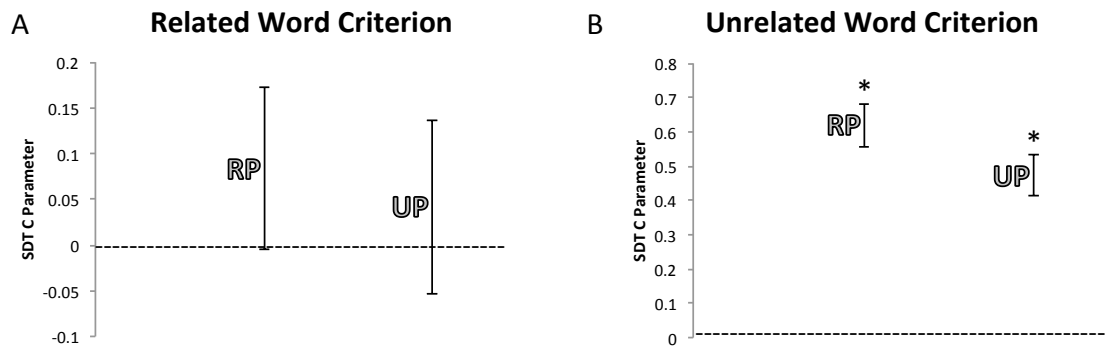


Figure 9. Signal Detection Theory C parameter by condition A) Related word C B) Unrelated word C. RP: Related precedent, UP: Unrelated Precedent * indicates significant difference, error bars represent standard error of the mean.

Discussion

These results provide insight into how studied information affects memorial decisions in situations with shared similarity of studied items. I successfully induced different levels of similarity bias by manipulating the proportion of related words and the type of word (Exp 1). I showed that as the bias for related words increased, the bias rate for unrelated words decreased. The Inverse List Length Effect (Dennis & Chapman, 2010) implicates the number of related words at study as the key factor resulting in the decrease in unrelated word false alarms. However, combining the present results and the results of White et al. (2013), it seems that proportion of related word to unrelated word is the crucial factor that leads to this result. This is because White et al. (2013) showed a similar bias for related words at test using the same proportion of words used here (in their medium and high related word conditions) but with a total of 96 studied words compared to the 24 studied words used in the present experiments. Further, Dennis and Chapman (2010) did not have participants study unrelated words and could therefore not take proportion of related to unrelated words into account. That being said, further research will be necessary to separate the effects of related word proportion from total related word.

To further explore the role of decision criteria in this relationship, I tested the related and unrelated words separately so that participants had the opportunity to adopt a different criterion for each set of words. I found that this eliminated the related word response bias, but not the unrelated word response bias. These results

suggest a complex interplay between memory strength including word specific and overlapping features, and decision criteria. More specifically, it is possible that criterion is set based on the overall memory strength for all studied words, and this criterion is suboptimal for each set of words individually (too liberal for related, too conservative for unrelated). This may lead to the “old” bias for related words, and “new” bias for unrelated words. When the “old” bias is diminished in the first experiment by changing the type of related word and the proportion, the “new” unrelated word bias is similarly diminished. This could be because the memory strength for each type of words is more similar, allowing for an overall criterion that is closer to being optimal for each set of words. The second experiment lends support for this conclusion because when the related words are tested separately, the “old” bias is diminished. This might be because participants are able to adapt a criterion that is only influenced by the related words when they are tested separately. This is because the relatively weaker memory for unrelated words no longer influences the criterion. This is partially supported by the results of the third experiment. If the memory strength is still increased for the related words when they are tested separately, but the criterion is allowed to be adjusted for these words, then this adjusted criterion should be relatively conservative compared to the criterion used when both types of words are tested together. Therefore, a pure related word test list should induce a relatively conservative criterion compared to a pure unrelated test list. This is partially supported by the results of the third experiment. The pure related precedent clearly subjected the unrelated words to a

more conservative criterion compared to the pure unrelated precedent. What follows is a more in depth discussion of the results of these experiments.

Memory Strength and Criteria Placement

Figure 10 depicts proposed explanations of the high response bias from experiment 1 (high proportion of negative emotional words) and the tested separately experiment 2 results within the Signal Detection Theory framework. Figure 10 A depicts old (black) and new (grey) distributions at a baseline orientation without any response bias. Figure 10 B depicts one account of the response bias observed in experiment 1. The related word distributions (black solid and dashed) are shifted to the right. This is caused by the encoding of related information that is applicable to all of these words making the words seem more familiar at test. The unrelated word distributions, which do not share any similarity, and are therefore considered less familiar, shift to the left. These results can be understood in terms of the Strength Based Mirror Effect (SBME, Stretch & Wixted, 1998). SBME is a well-established phenomenon in which stronger memory for studied words leads to a higher hit rate and a lower false alarm rate at test. This effect has been replicated using multiple strengthening manipulations including repeating items on the study list (Stretch & Wixted, 1998), Increasing encoding time (Ratcliff, Clark & Shiffrin, 1990), decreasing the retention interval (Singer & Wixted, 2006) and displaying pictures instead of words (Israel & Schacter, 1997). Criss (2009) claimed that SBME is caused by the differentiation of the studied from the

unstudied words. The difference between similarity discussed here and the usual ways in which SBME is observed is that similarity is applicable to all related words, studied and unstudied. Generally, SBME is observed by increasing the memory strength for studied items leading to a mirroring of the hits and false alarms. However, the same basic principles still apply here. similarity being applicable to all related words is only different than the SBME strength manipulations because it does not lead to an increase in overall accuracy for these words, but rather a shift in bias. This is because the related word false alarm rate increases as well. The same differentiation process should still apply. In the same way a strength manipulation leads to greater encoding of studied words and results in an increase in hits and a decrease in false alarms; similarity could be increasing related word memory strength, and decrease unrelated word memory strength in the same way.

Conversely, Starns, White & Ratcliff (2012) show that the SBME can be explained through changes in the decision making process and not memory differentiation. Conventional wisdom states that when memory for a set of words is increased participants adjust their decision criteria so that more evidence is needed to elicit an “old” response (Brown, Lewis & Monk, 1977; Hirshman, 1995; Stretch & Wixted, 1998). This has been shown to be a sufficient explanation for SBME without the need for differentiation (Starns, White & Ratcliff, 2012). It stands to reason that both differentiation and criteria placement could be applicable here. It is difficult to conceptually separate these two theories in terms of the unrelated word distributions because either account leads to an increase in the amount of memory strength necessary to elicit an “old” response for the unrelated words. The

difference comes when considering whether the amount of evidence available changed, or the amount of evidence needed has changed. It is possible that both are true, the amount of evidence for unrelated words decreases, and the criteria to elicit an “old” response increases.

In experiment 2 I tested participants on the related and unrelated words in pure consecutive blocks so that participants would have an opportunity to use a different decision criterion for each set of words (Starns, 2010). I have shown that this manipulation eliminates the related word response bias, but the unrelated word response bias remains. I depict our proposed explanation for these results in 10 C, which is supported by the results of the third experiment. As previously discussed, both differentiation and criterion shift explanations for SBME include the strengthened word distributions shifting to the right, indicative of stronger memory for these words. I equate the related words with a strengthened set of words, and have therefore depicted these distributions shifting to the right in figure 10 C. The only way to explain these results with the inclusion of the memory strength increase for related words is for the criterion to shift to the right as well, increasing the amount of memory strength required to elicit an “old” response, and moving far enough to eliminate related word response bias. This is logical considering the probability that participants can adopt a different criterion for related and unrelated words. In the first experiment presumably only one criterion was being used, resulting in a criterion that is somewhere in between where the ideal place for each individual criterion for both sets of words would be. The results for the unrelated word in experiment 2 are more difficult to explain. The response bias to

call these words “new” is still present when the words are tested separately. This is because the unrelated word distributions shifted to the left and/or the criterion for these words is still somehow influenced by the related words, and is possibly the same criterion placement used in experiment 1.

Prior Expectations

The standard test list in the DRM paradigm consists of 50% studied words. Some studies have manipulated the proportion of studied words at test to see how this may alter response bias (Criss, 2009; Healy & Kubovy, 1978; Ratcliff, Sheu & Gronlund, 1992; Rotello, Macmillan, Hicks & Hautus, 2006). The results of this manipulation vary, but in general, the increased proportion of studied words at test leads to a slight increase in an “old” response bias. However, in an extreme example, Cox & Dobbins (2011) tested participants on a test list that was either purely studied or unstudied words. They showed no increase in the hit rate compared to standard test list proportions and only a subtle increase in the false alarm rate. While these drastic results may not be consistent with most reports, it is clear that participants’ response rates are not entirely dependent on test list proportions, and may only be subtly affected by these manipulations.

A few explanations for these results have been proposed. Both explanations claim participants have learned an expected proportion of studied words based on previous experience. One account describes this in terms of reinforcement learning history (Mickes, Hwe, Wais & Wixted, 2011) and the other in terms of preexperimental prior beliefs (Turner, Van Zandt & Brown, 2011).

While the present study only used the standard 50% studied words at test, the role of prior test list expectations could play a role in explaining our results. The participants of the current study were not told what the proportion of studied words at test would be. It is reasonable to postulate that their prior expectations would be a standard 50% studied words at test. However, the related words feel more familiar, and therefore elicit the old response more often. To stay true to their prior expectations, they may compensate for this high similar word old responding by being more frugal with their old responding for dissimilar words, leading to a perceived 50% old responding for the entire test list. This could also explain the decrease in old responding for related words when they are tested separately. Without the neutral words to counter the high old responding, the participants compensate by decreasing old responding for similar words.

Limitations/Future Directions

These experiments do not address the temporal role of similarity in memory. More specifically, if I analyze response times from these experiments, I may be able to shed light on how similarity influences the decision making process over the response time course. It has been shown that having participants scroll a mouse to indicate their decision can provide insight into the decision-making process overtime (Koop, 2013). If I have participants scroll a mouse to indicate their response in the experiment discussed presently I may be able to better observe the role of similarity in memory during the decision-making process. Further, I plan to

model this data using the Ratcliff drift diffusion model (Ratcliff, 1978; Ratcliff & McKoon, 2008, Ratcliff, van Zandt & McKoon, 1999). This is a reasonable framework to use for this situation because the drift diffusion model accounts for speed varying two choice decision tasks like the one presently discussed.

Conclusion

Here I induced different levels of similarity response bias. I did this by manipulating the proportion and type of related words and found that as the related word bias rate increased, the unrelated word response rate decreased. I then tested the related and unrelated words separately to allow for different decision criteria to be adopted. This manipulation eliminated the response bias for related words but not the unrelated words. For the third experiment, I subjected participants to a pure related or unrelated word test list that progressed into a mixed test list. Upon analyzing the mixed test lists, here I showed that the pure related word precedent lead to a more conservative criterion for the mixed list, at least for the unrelated words. These results suggest a complex relationship between perceived memory strength and decision criteria. Generally speaking, I found evidence that related items produced stronger familiarity than unrelated items, and influenced decision criteria such that participants became more conservative to offset the increased familiarity of the tested items. While I was unable to definitively identify the specific processes responsible for these results, it is clear that unrelated word

response rate is an important aspect of similarity in memory, which warrants further attention.

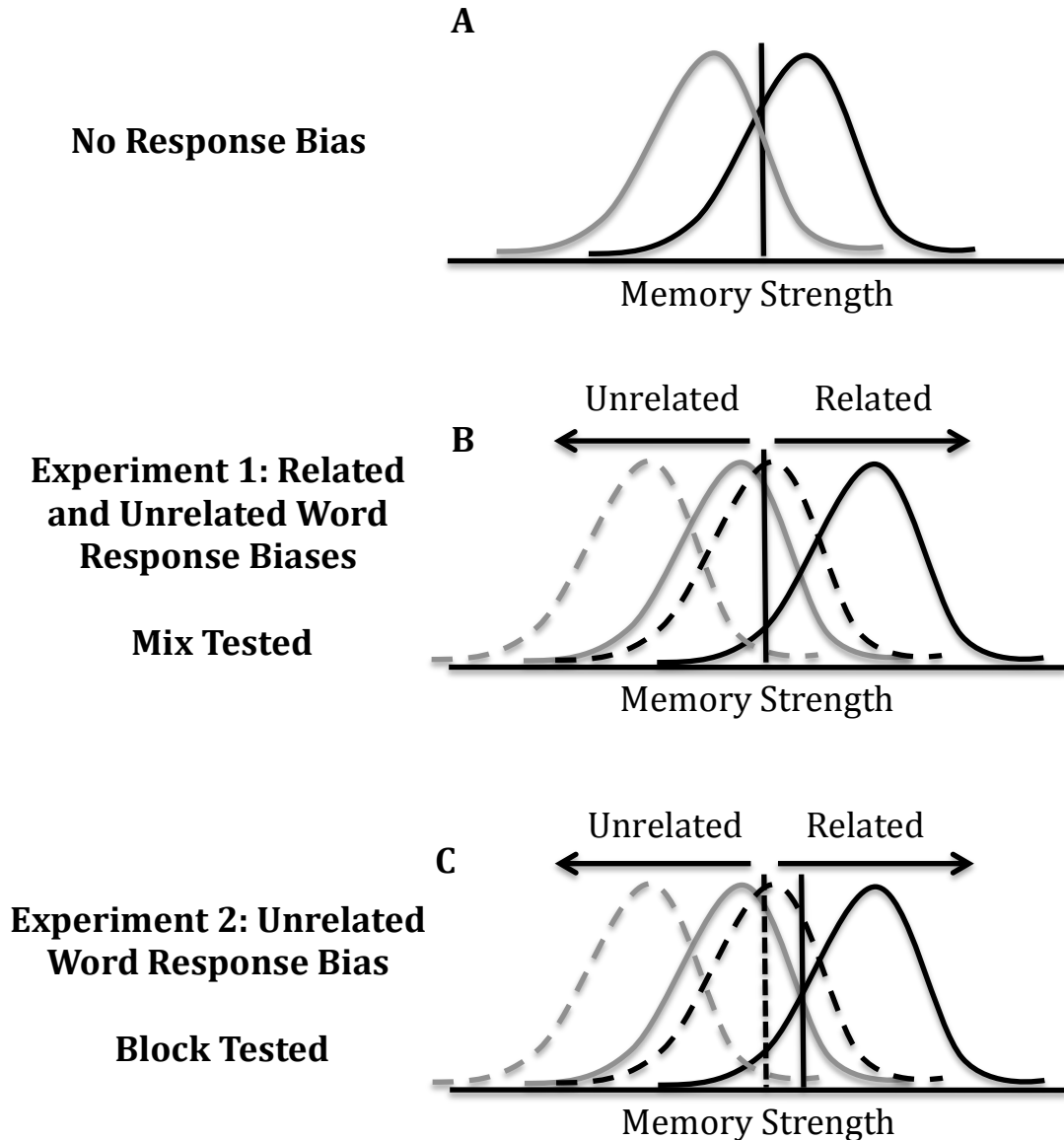


Figure 10. Signal detection depiction of results from experiment 1 and 2. A) Normal distributions of hits (black) and false alarms (grey) depicting no response bias. B) Depiction of proposed signal detection layout of word response biases observed in experiment 1. Solid = hits, dashed = false alarms, black = related words, grey = unrelated words. The related word distributions move to the right, unrelated distributions to the left. Criterion could move slightly to the right but is not depicted here (see text). C) Depiction of proposed signal detection layout of word response bias observed in experiment 2. Solid = hits, dashed = false alarms, black = related words, grey = unrelated words, dashed line = unrelated word criterion, solid line = related word criterion. Related and unrelated word distributions move in the same way as in B. However, a separate criterion is used for the related and unrelated words leading to the lack of a related word response bias.

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Appendix A: Pure Word List Experiment

Pure related and unrelated study and test lists were administered in order to observe the response rates to each type of word without the influence of the other. These experiments used the same methodology described in experiment one but with study and test lists consisting entirely of related or unrelated words. 44 and 46 participants received the related and unrelated lists respectively. The goal of this experiment was to have another comparison for the “old” and “new” biases discussed throughout this paper. If the distinction perceived at study and/or test between related and unrelated words produces these biases, the pure lists could be used as appropriate bias free controls. However, the difference between the experiment one negative high proportion group and the pure related experiment discussed here was primarily seen in accuracy. The pure related experiment produced considerably superior accuracy compared to the negative high proportion group. This is an interesting result that exemplifies the issue disentangling accuracy and bias. The negative high proportion and pure related groups have similar hit rates. These hit rates are the two highest observed in any experiment discussed here. The difference in accuracy is carried entirely by changes in the false alarm rate. It is possible that the hit rates are approaching a ceiling and therefore bias can only be seen in changes in false alarm rates.

The difference in accuracy could also be caused by changes in encoding caused by the presence or absences of the distinction between related and unrelated words. For example, It is possible that the lack of distinction results in a depreciated in related word gist information and results in more encoding of item specific information. While this is an interesting line of research, it is separate to the hypotheses discussed in the present article.

Group	Hits		FAs		C		d'		A'	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Related	0.781	0.091	0.228	0.110	-0.010	0.278	1.636	0.549	0.854	0.060
Unrelated	0.732	0.103	0.327	0.163	-0.096	0.409	1.113	0.448	0.780	0.108

Table 3 Pure Experiment Data. Mean and standard deviation of response rates, C and d' by type of word (related or unrelated).

Appendix B: Response Times

I observed response times for each group in experiment one and two. There is some evidence that related words are considered “old” faster and correctly rejected more slowly if the related word “old” and unrelated word “new” biases are present. This may indicate early attention on gist information consistent with the related word category. In depth analysis of this data is a future direction but is beyond the scope of this work.

Group	Related								Unrelated							
	Hit		False Alarm		Correct Rejection		Miss		Hit		False Alarm		Correct Rejection		Miss	
EXP 1	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Negative High Proportion	0.773	0.25	0.886	0.32	0.873	0.274	0.876	0.308	0.798	0.254	0.91	0.317	0.801	0.256	0.876	0.308
Animal High Proportion	0.791	0.247	0.911	0.319	0.89	0.276	0.919	0.316	0.825	0.253	0.939	0.327	0.855	0.262	0.919	0.316
Negative Low Proportion	0.837	0.305	0.933	0.388	0.859	0.33	0.886	0.445	0.818	0.292	0.903	0.401	0.859	0.33	0.886	0.445
Animal Low Proportion	0.763	0.308	0.753	0.402	0.815	0.304	0.779	0.39	0.75	0.295	0.747	0.437	0.797	0.326	0.756	0.356
EXP 2																
Test Separation	0.811	0.283	0.95	0.364	0.883	0.296	0.911	0.341	0.829	0.308	0.898	0.42	0.871	0.304	0.913	0.365

Table 4 Experiment 1 and 2 Response Time Data. Mean and standard deviation of response times, grouped by hits, false alarms, correct rejections and misses of related and unrelated words in each group.

Education

- **University of Buffalo**, Buffalo, NY
11/2012
 - M.S. Neuroscience
- **Daemen College**, Amherst, NY **5/2006**
 - B.S. Psychology, Dean's List
- **Syracuse University**, Syracuse, NY **9/2014-**
 - PhD Candidate Experimental Psychology

Research Experience

- **Behavioral:**
 - Rotarod
 - Filmed Open Field
 - Filmed Cylindrical Field
 - Elevated Plus
 - Beam Walk
 - Forced Swing
 - Novel Olfactory Recognition
 - Olfactory Habituation/Dishabituation
 - Prepulse Inhibition (PPI)
- Subcutaneous and intraperitoneal injections of mice with various therapies and/or toxins
- Colony maintenance, genotyping, and breeding of isogenic transgenic animals
- Stereotaxic rodent surgery: implantation of microdialysis probes and generation of stroke model Pial Vessel Disruption
- Intensive animal care including symptom identification and treatment
- Mouse gavage feeding
- Animal sacrifice and neurological tissue processing
- Utilizing Noldus Ethovision XT to quantify animal behaviors
- Data analysis using PASW (SPSS)
- Administration and analysis of attention and memory experiments in Dr. Corey White's Brain and Behavior Laboratory
- **Molecular Biological/Neuroanatomical:**
 - Immuno precipitation
 - Western blots
 - Polymerase Chain Reaction (PCR)
 - Fluorescence Microscopy
 - Immunostaining
 - Neurostereology using Visiopharm software
 - High Performance Liquid Chromatography (HPLC)
 - Positron Emission Tomography (PET) scans

Teaching Experience

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Teaching Assistant

- Neuroanatomy, University at Buffalo School of Dental Medicine

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- Foundations of Human Behavior (PSY 205), Syracuse University Psychology Department

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Instructor

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Professional Experience

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Research Technician

- Dr. Stachowiak Laboratory for Molecular and Structural Neurobiology and Gene Therapy
 - Western New York Stem Cell Engraftment and In Vivo Analysis Core Facility
 - Stereology Laboratory
 - Western New York Stem Cell Behavioral Analysis Core

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Psychometrician

- Data upkeep and analysis using PASW (SPSS)
- Survey creation
- Survey administration
- Survey administration training

Publications

Stachowiak, M.K., Kucinski, A., **Curl, R. A.**, Syposs, C., Yang, Y., Narla, S., Prokop, D., Klejbor, I., Bencherif, M., Birkaya, B., Corso, T., Parikh, A., Tzanakakis, E. S., Wersinger, S., Stachowiak, E.K. (2013). Schizophrenia: a neurodevelopmental disorder – integrative genomic hypothesis and therapeutic implications from a transgenic mouse model. *Journal of Schizophrenia Research*. 143(2-3), 367-76.

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Frontiers in Psychology.

Presentations

Curl, R. A., Sloane, J. F., & White, C. N. (2015). *Exploring the representation of semantic similarity in recognition memory*. Poster presented at the Annual Meeting of the Psychonomics Society, Chicago, IL.

Curl, R. A., White, C.N. (2014). *Temporal dynamics of semantic similarity in recognition memory decisions*. Poster presented at the Annual Meeting of the Psychonomics Society, Chicago, IL.

Curl, R. A. (2011). *Impaired performance on an object recognition task suggests a working memory deficit in a mouse model of schizophrenia*. University at Buffalo Annual Poster Presentation.

Curl, R. A. (2010). *Group distinctiveness, group identity and perceived intergroup threats*. Daemen College Psychology Department Academic Festival Thesis Poster Presentation.

Honors and Awards

International Meeting of the Psychonomic Society 2016: Graduate Accommodation Award

Reviews

Ad hoc reviewer: *Journal of Experimental Psychology: Learning, Memory and Cognition, Cognitive Psychology, Memory and Cognition*.

References

Available upon request